

# **WORLD BANK GROUP'S ENERGY AND ENVIRONMENTAL STRATEGY AND CLEAN COAL PROGRAM**

**Masaki Takahashi**  
**Senior Power Engineer, The World Bank**

## **INTRODUCTION**

Developing countries will not be able to lift themselves out of poverty without increased use of modern forms of energy. Even with increasing use of renewable energies, demand will grow, and will be met by fossil fuels, in many cases coal. However, worsening air pollution caused by coal use is significantly affecting human health, damaging the environment and having a significant impact on output of gross domestic product (GDP). Greenhouse gas emissions from developing countries, though still lagging behind those from industrialized countries, will grow. These circumstances create a powerful mandate for cleaner and more efficient use of fossil fuels in developing countries.

This paper presents the World Bank's perspective on environmental strategies for energy sectors in the next century: "Making Markets Work and Integrating Environmental Costs." The paper also presents the Bank's clean-coal programs and the methodology of key findings for its technology-assessment and environmental-options case studies in India and China. In India, a study on environmental issues in the power sector has been completed, and methodology developed and applied to two states: Andhra Pradesh and Bihar. In China, a thorough energy-environment assessment was carried out in Shanghai, Henan and Hunan provinces, including least-cost compliance planning, assessment of the cost-effectiveness of power- and non-power-sector options, dispersion modeling, and environmental externalities. These methodologies will be able to be replicated elsewhere in India, China or other developing countries.

A strategy paper titled "Environmental Strategy for the 21<sup>st</sup> Century in Energy Sector" was approved by the board of directors of the World Bank in July 1999. The paper enhances the World Bank Group's existing energy-sector policies on structural and institutional reform, energy efficiency improvement, and rural energy (access to modern energy); it also proposes a new policy of environmental protection in energy sector. In the new strategy, the World Bank Group (WBG) promotes clean energy and clean technology.

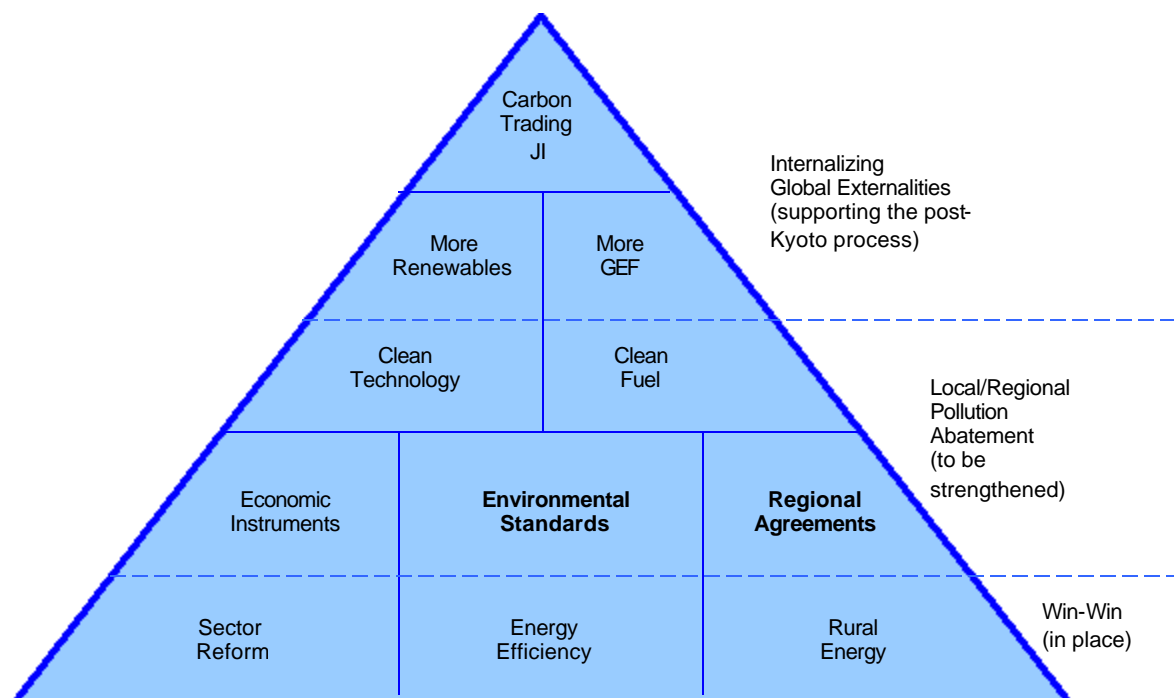
## **1) WBG ENERGY AND ENVIRONMENT STRATEGY**

In the early 1990s, the WBG instituted a policy to change its energy sector lending; structural and institutional reform, energy efficiency and rural energy (energy access) strategies are found at the bottom of the WBG Energy and Environment Strategy pyramid in figure 1. The strategies are as follows:

- In general, the WBG will only invest in a country's energy sector if that country shows commitment to improving efficiency by restructuring the sector or reforming its policies to support further sectoral restructuring or policy reform.
- WBG will support competition, private-sector investment, and sound regulation of the sector.

- WBG will promote energy efficiency on the supply side and the demand side, and integrate energy pricing with environmental policies.
- There are two billion people in rural areas who are still dependent on traditional biomass energy for their various activities. WBG will help improve access to modern forms of energy for these people, who must rely on traditional forms of energy such as fuel wood and agricultural waste.

The change of policy makes large-scale World Bank lending projects a tool to accomplish the strategies mentioned above, rather than lending for operational costs, no longer an objective of the Bank.



**Figure 1. Fuel for Thought: Environmental Strategy for the Next Century**

### **1.1 Making markets work**

Sector reform and institutional reform are the highest priorities for the WBG. Unless developing countries agree to promote energy sector reform, the WBG would not even think of financing projects for them.

MAKING MARKETS WORK	
•	Pricing
•	Reform
•	Energy efficiency
•	Fuel switching
•	Power and gas trade

### **1.1.1 Energy price**

In developing and industrialized countries, coal has been provided various subsidies and some type of protection by the governments. In these cases, there is no market mechanism working effectively in the coal markets. We must, therefore, provide some kind of scheme that motivates producers of coal to produce high quality coal. The cost of environmental damage has never been included in coal prices. When coal is used in power generation, environmental control costs such as installing Flue Gas Desulfurization (FGD) equipment can be added to the cost of electricity to recover capital investment and operation and maintenance costs. This has been a typical method of cost recovery, and without it, clean coal technology or environmental controls have not been successfully promoted. However, when coal is used in households for cooking and space heating, or in small industrial boilers as a heat source, it is difficult to monitor emissions because the number of emission sources is so large; it is also difficult in this situation to add environmental control costs to the product price. In these cases, therefore, it would be more reasonable and effective to include environmental costs in the coal price itself.

### **1.1.2 Sector reform**

In the past, national authorities such as ministries or departments of power generated and distributed electricity. But the regulating function and electricity-supply function have been split between such government authorities and utilities. State owned utility companies have been privatized, or the power generation market has been opened to private Independent Power Producers (IPP) in many developing countries; the WBG supports these structural and institutional reforms in power sectors. In many countries in Latin America, Southeast Asia and South Asia, there are a growing number of private companies getting into the power generation business. There are fewer and fewer cases of the World Bank's International Bank for Reconstruction and Development (IBRD) providing financing to public utilities for power generation projects. In the WBG, the International Finance Corp. (IFC) provides investments and finance to the private power projects. IBRD and MIGA provide guarantees and insurance, respectively, to promote private power projects.

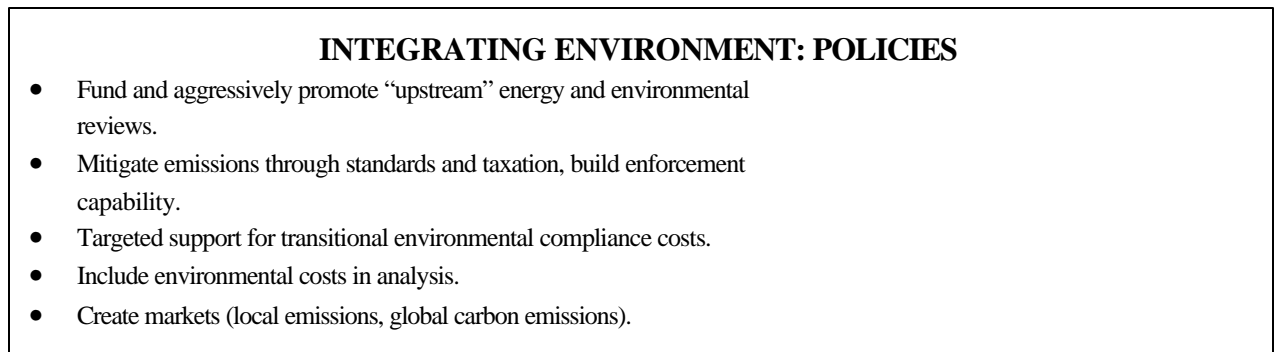
To promote clean-coal and environmental-control technologies, there is a need to enable the private sectors that are willing to invest in such technologies by setting emission standards, emission credit allowances, and emissions fees. In other words, environmental costs need to be included in the market mechanism; to promote the private investment, there must be a system by which environmental costs can be incorporated into the cost of electricity.

### **1.1.3 Energy efficiency improvement**

The World Bank's energy efficiency improvement projects are mainly in demand side management (DSM). On the supply side, much emphasis has been put on the reduction of transmission and distribution loss. This is because in most developing countries, these areas have been inefficient and improvements in these areas have been most cost effective.

The improvement of power generation efficiency has been considered to be technical, without a great role for the WBG to play. However, rehabilitation of the power plant, the

supercritical technology, pressurized fluidized bed combustion (PFBC) and integrated gasification combined cycle (IGCC), will improve energy efficiency significantly and reduce coal consumption per unit of electricity generated, thus reducing CO<sub>2</sub> and other emissions. Development, demonstration and deployment of these technologies in developing countries requires large amounts of investment and financing, and for this function, the WBG can play an important role.



**Figure 3. Integration Strategies**

## **1.2 Integrating environment into Policy**

### **1.2.1 Energy and Environmental Reviews**

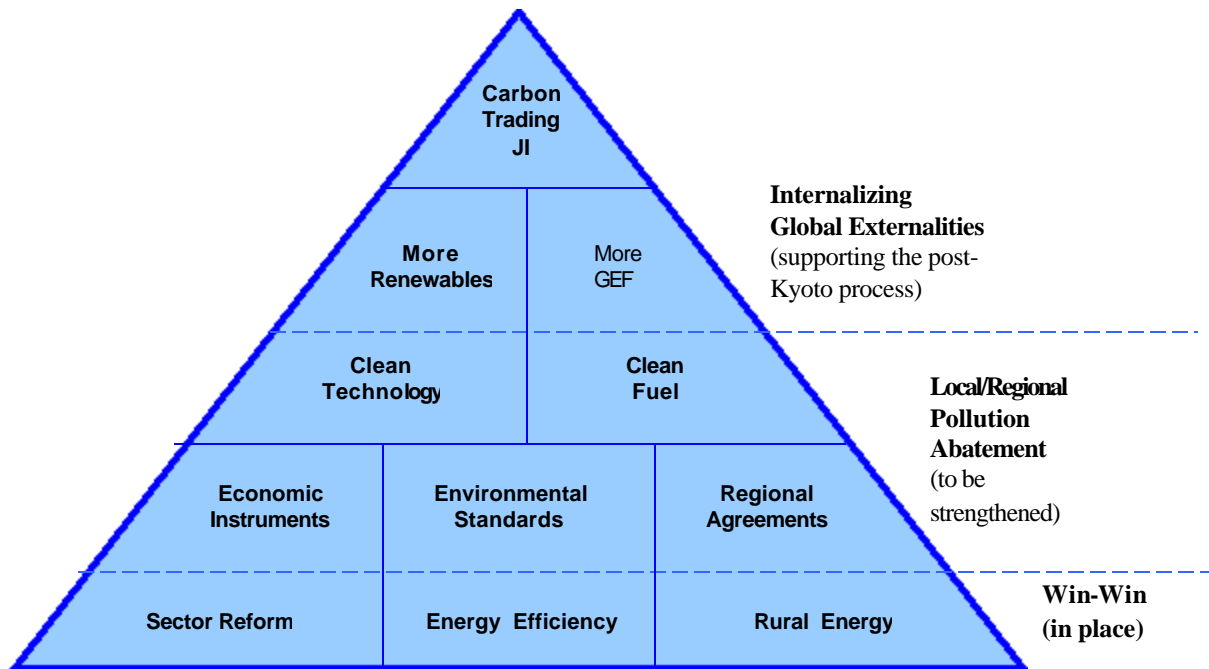
The WBG will undertake a program of Energy-Environmental Reviews (EERs) that will cover the whole energy chain and the whole range of its environmental impacts. EERs will help map out what the WBG will do regarding energy supply and demand, and pollution avoidance and control, in areas such as efficiency, conservation, rehabilitation, and decommissioning. Rather than focusing on each project, the review will assess the integrated environmental impact of several energy scenario options. The review will also help to develop environmental policy by setting environmental standards that promote cost-effective environmental protection. Case studies in India and China are the preceding activities of the EERs, and other review projects will follow in Mexico, Sri Lanka, and Turkey.

The WBG updated the environmental guidelines and published the “Pollution Prevention and Abatement Handbook” in August 1998. Developing countries’ governments will be encouraged to use the *Handbook* to review existing conditions against international standards and prepare a set of pollution guidelines adapted to local circumstances. Assistance will be provided through the EERs and follow-up technical consultation to raise public awareness of the costs and benefits of environmental clean-up, to help governments install pollution monitoring equipment, and to build institutions able to monitor and enforce the standards.

### **1.2.2 Internalizing environmental impact costs**

To internalize environmental-impact costs, there are several policies that can be followed, including setting environmental standards and enforcing them, creating emissions trading markets, and imposing emission fees or taxes. To implement these institutions

appropriately, we must first understand the energy and environmental situations in developing countries. We could give policy and technical advice and financial support based on the experience of industrialized countries. The WBG will support creation of local and regional emissions trading markets for particulates, SO<sub>2</sub> and NO<sub>x</sub> emissions, as well as creation of a global emissions trading market for CO<sub>2</sub> and other greenhouse gases through, for example, a Prototype Carbon Fund (PCF).



**Figure 4. Fuel for Thought**

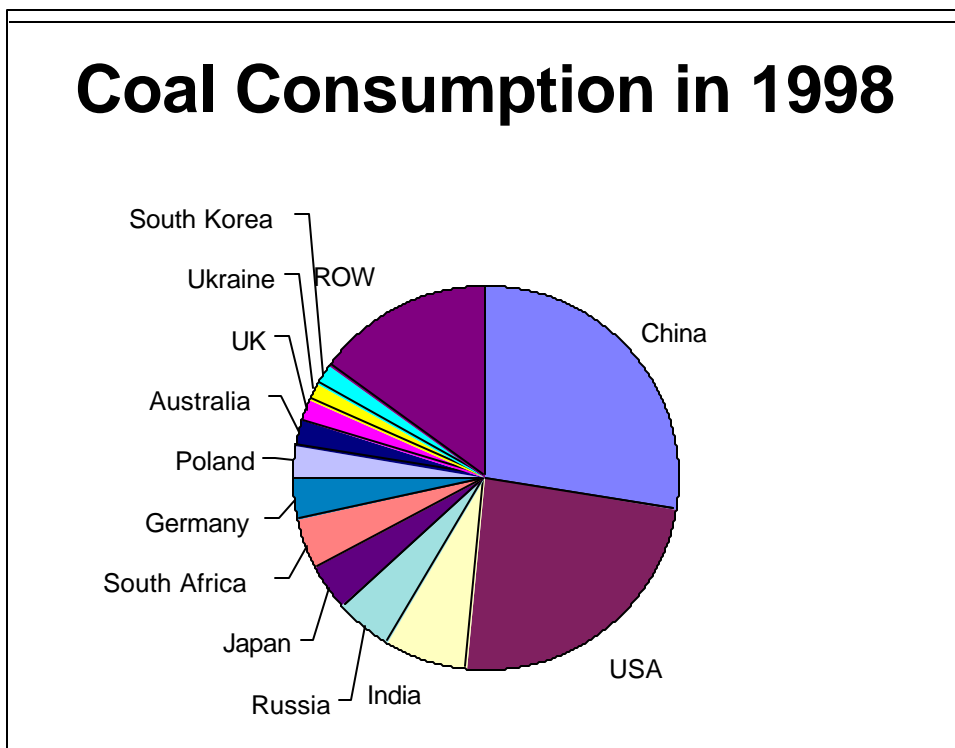
Referring to the pyramid chart (Figure 4), we can review the role of the Energy and Environmental Review (EER) in the WBG's Energy and Environmental Strategy. At the second level from the bottom, EERs will help set each country's environmental standards and establish regional environmental agreements by applying the WBG's environmental guidelines. The third level from the bottom includes clean technologies and clean fuels, and the WBG will use its financial tools to promote them; solar, wind, biomass and other renewable energies are included here. The amount of financing is still limited, but the number of World Bank staff and consultants engaged is about ten times more than those engaged in clean coal technology.

Natural gas development, small- and medium-size hydroelectric development, and clean coal technologies will follow the path of renewable development. These activities, however, have just started, and when we consider the important role of fossil energy in developing countries, we must really regard these matters as much more important issues. The top of the pyramid is related to global warming and reduction of greenhouse gases. Here, the Global Environmental Facility (GEF) has played a very important role. As for coal-related projects, there is only the industrial boiler project in China; the GEF fund is

used to improve industrial boiler efficiency in China by providing license fee payment. To improve plant efficiency with clean coal technology, , supercritical technologies, PFBC and IGCC could theoretically be funded by the project. Currently however, only IGCC is clearly named in the operational policy of GEF, and no funds are provided to projects using these advanced clean-coal technologies (CCTs).

## 2) CLEAN COAL PROGRAM AND CASE STUDIES IN CHINA AND INDIA

Coal Consumption in 1998 (Figure 5) shows BP Amoco statistics on coal consumption by country in 1998. China consumes 28% of all coal, followed by the United States (24%), India (7%), Russia (5%) and Japan (4%). It is therefore reasonable that the World Bank's clean coal program would focus on China and India. In India, we have projects that reduce the impact of coal on the environment and society, and studies have been done on environmental issues in the electric power sectors in Bihar and Andhra Pradesh.



**Figure 5. Coal Consumption in 1998**

The case studies in India and China are separate activities managed by different managers, each with a different focus, taking cross-cutting and different methodological approaches; we are learning from and compensating each other. "Environmental Issues in the Power Sector," with case studies in India, focuses on the power sector and covers a wide range of options including sector reform, demand-side management (DSM), transmission and distribution (T&D) rehabilitation and renewable technologies, while clean coal technology options are limited to a few selected options and more attention is paid to coal ash management. In China, the "Clean Coal Technology Assessment and

Environmental Control Options Case Study” covers comprehensive options in coal utilization technologies for both power and non-power sectors.

## **2.1 Case Studies in India**

Based on the findings of the case study in India, the following main conclusions emerge:

- continuation of current policies and practices in the power sector is not sustainable in financial terms, and will lead to even more harmful impacts on the environment than in the past;
- economic pricing of fuels, which internalizes environmental impacts, will improve the situation;
- options are available to further ameliorate the situation, but they need to be implemented in combination to achieve maximum reductions in environmental impacts; and,
- the changes in incentives that are likely to follow from power sector reform should greatly benefit the environment.

### **2.1.1 Current Policies and Practices**

Continuation of current policies and practices in the power sector is not sustainable in financial terms, and will lead to even more harmful impacts on the environment than in the past. If current tariff policies are maintained, the financial performance of the power sectors in both Andhra Pradesh and Bihar will impose an insupportable financial burden on their respective state governments. The rate of return on capital in Andhra Pradesh will become increasingly negative in years to come, reaching –18% by 2015, while in Bihar it would average –14% from 1996 through 2015. The financial injections that would be necessary from the respective state governments to ensure a minimum flow of funds to maintain and operate the sectors is unlikely to be forthcoming.

The analysis draws attention to the important relationship between the poor financial condition of the two state electricity boards (SEBs) under current policies, and their inability to comply fully with environmental standards. All the thermal power plants in Andhra Pradesh are fitted with controls to limit the levels of total suspended particulates (TSPs), but many units, particularly the older ones, are unable to meet the standards due to managerial and technical problems, including inadequate maintenance.

Under current policies, emissions of environmentally damaging combustion products may be expected to increase rapidly, doubling in Bihar and quadrupling in Andhra Pradesh by the year 2015. Extrapolating these results to India reveals serious conditions. Emissions on this scale are bound to affect air quality and have major human health impacts. The damages caused by particulate matter to the respiratory system are a particular concern. Consequences include significant increases in mortality, in hospital admissions for respiratory infections, in emergency room visits for bronchitis and other chronic pulmonary diseases, and in the number of days asthmatics experience shortness of breath and residents experience restricted activity.

Although the power sector contributes to the problem, most of the pollution, especially in urban area, stems from other sources, notably residential and commercial stoves, industrial boilers, inefficiencies in the transport sector and the liquid fuel chain, extensive use of traditional fuels in city slums, and emissions from non-energy sources. Urban air pollution is, therefore, a cross-sectoral issue that requires a citywide approach to achieve

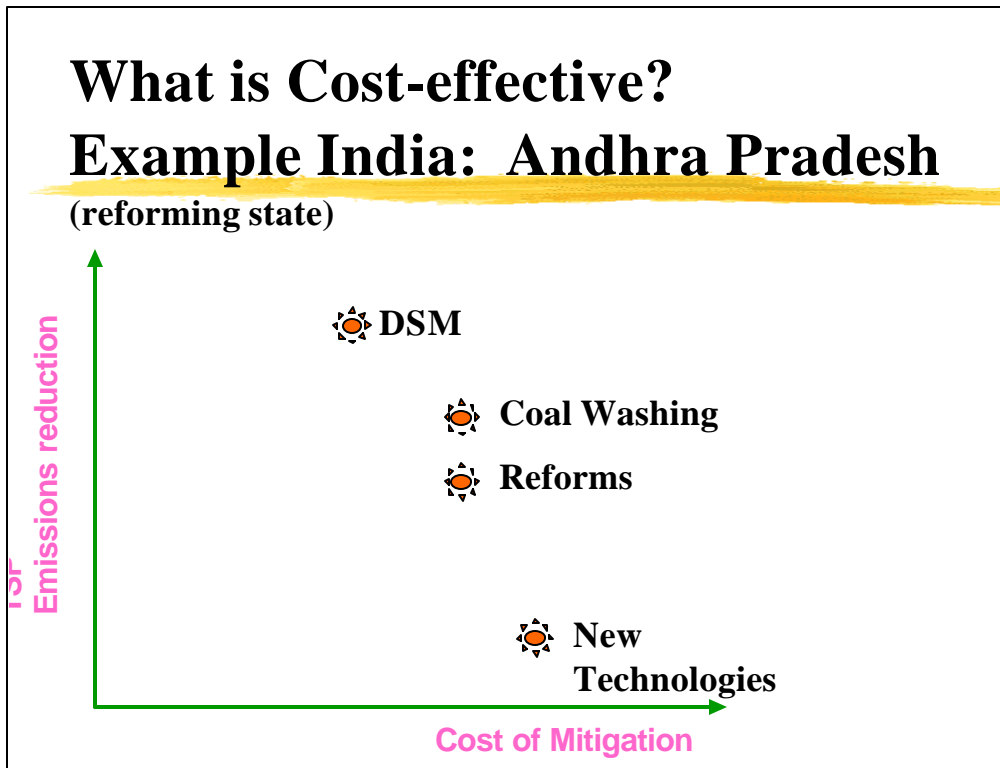
comprehensive air quality management. Thus, a strategy to address urban air pollution must integrate a range of activities at the municipal level, especially at small sources such as energy and power stations in densely polluted areas, and in the transport sector. This strategy should also include a major focus on the petroleum sub-sector.

Currently the power sector in India is on the verge of fundamental reforms that have profound implications for environmental management. India is moving from a publicly owned, vertically integrated, monopolistic power system with highly distorted prices for fuels and electricity to a more liberal system with market prices, (competition?), a greater role for the private sector, and commercial incentives. These changes will affect every aspect of the energy production system: the demand for electricity, the financial viability of all involved entities, the choice of fuel and technologies, pricing decisions, and the roles and relationships of the state, the power sector, regulators, and fuel suppliers.

During this time of transition, it is critical to determine how best to take advantage of the opportunities presented to protect the environment and avert threats to public health.

Depending on the unique needs and situation of the geographic area, different strategies may be more or less effective for reducing negative environmental consequences from power generation. Decision-makers can choose from a range of measures, using modeling tools to determine which combination of options will have the greatest positive impact. For example, the environmental impacts of power development may be reduced by using less electricity, by preventing waste products from reaching the environment, by adopting cleaner technologies for coal production, or by using alternative forms of energy production that cause less environmental damage. Sound pricing strategies for electricity and fuel, changes in the structure of a power sector, and taking environmental impacts into account when determining the cost of energy production would also help preserve environmental quality.

While planning for power system expansion previously has been conducted at the national level using state-provided data on regional needs, the decision-making process in India is being decentralized. Some SEBs are being unbundled into separate generation, transmission, and distribution entities. Corporatization and, to an increasing degree, privatization are an integral part of this process. The unbundled institutions will assume responsibility for the critical functions of planning and decision-making.



**Figure 6. Cost effectiveness in India**

Options available to India as it seeks to reduce the environmental impacts of power generation include the following:

- reforming and restructuring the power sector;
- rehabilitating generating plants and transmission and distribution networks;
- managing demand with power sector reform;
- using renewable energy supplies;
- internalizing the cost of pollution;
- reducing and recycling combustion byproducts; and,
- siting plants to reduce environmental damage.

### **2.1.2 Reforming and restructuring the power sector**

No sustainable environmental mitigation policy can be envisioned without power and coal sector reform. Though it is moving toward reform, India's current government policies continue to maintain some fuel prices at artificial levels, with inevitable and harmful consequences to the environment. While most coal prices have been deregulated, power-station grades of domestic coal are still priced below the cost of production, and the true value of the better grades is underestimated. Cleaner imported fuels are priced too high by comparison with domestic coal. Also, prices for the transport of goods by rail, including coal, are generally subsidized, further encouraging the use of the domestic product and its high ash content. As a result:

- Indian coal is preferred as a fuel for power generation over other fuels with lower ash content;

- the relative prices of different grades of coal give no incentive to coal producers to increase output of better-quality coals;
- distorted prices for transport affect the choice between pit-head and load-center plants, shifting the location of environmental impacts; and,
- demand is maintained at artificially high levels.

As the government reform progresses and prices for fuel rise to a level that reflects their true economic costs, stakeholders in the energy system will have reasons to make different choices. When the tariff structure is changed to reflect the economic costs of production, higher prices for electricity in the residential and agricultural sectors will dampen demand. As electricity producers are motivated by commercial incentives rather than dependence on government subsidies, they will have adequate cash flow to rehabilitate transmission and distribution systems and to modernize generating plants, reducing electricity loss through inefficiency. Commercial incentives will encourage power utilities to offer higher prices for better coal, and will spur coal suppliers to invest in coal beneficiation plants. Commercially motivated producers will search for cost-effective ways to encourage ash utilization and disposal; they also will improve metering, monitoring, billing, and collection procedures, which will increase the amount of available cash. Finally, power system reliability will increase, and many consumers who now install their own power sources will be able to rely on the grid system.

### **2.1.3 Rehabilitating Transmission and Distribution Networks**

Losses of energy as a result of weaknesses in India's transmission and distribution system were reported by public sector utilities to be as high as 21%. This figure is generally recognized as a serious underestimate by experts familiar with the power sector in India. Most state-level studies cite a much higher percentage— perhaps even double the public utility figure. These losses are much greater than in East Asian countries, where the best performers were the Republic of Korea (10.2%) and Singapore (9.1%). Factors that contribute to the high rate of loss in India include:

- lack of investment in rehabilitation of the transmission and distribution systems;
- weak transmission and distribution lines;
- long transmission and distribution lines;
- low power factor operation;
- too many transformation stages; and,
- pilferage and theft.

Modeling suggests that the percentage of power lost through transmission and distribution could be reduced in most states to as little as 10% by 2010. If energy providers are motivated to make improvements through price reform, changes in maintenance, metering, monitoring, and billing and collection would make more money available to rehabilitate the system – clearly a win-win prospect. System rehabilitation not only would result in across-the-board reductions in environmentally damaging emissions, but in financial and in economic benefits to society.

Case studies found system improvements to be cost-effective both in Andhra Pradesh and in Bihar, which has a smaller system in worse condition. Both are currently experiencing energy losses of 30% or more. By rehabilitating the existing transmission and distribution systems, both could significantly reduce operating costs and achieve measurable environmental benefits for area residents.

In Andhra Pradesh, measured environmental impacts would be reduced by 3% and operating costs by 4%. In Bihar, impacts would be reduced by 5 to 6%, and expenditures on operations would fall by more than 6%.

#### **2.1.4 Internalizing the cost of pollution**

The government is responsible for setting the rules for how environmental costs are borne by polluting agencies, to encourage reducing or maintaining environmental waste at acceptable levels; this is called “internalizing” the costs. If the rules of environmental management set by the government were adequate and enforced, all costs would be internalized within agencies. Agencies would be motivated, by whatever means chosen by policy makers, to fully bear these costs, and would therefore make the changes needed to reduce emissions. This can be accomplished by using technical standards that require polluters to reduce emissions to target levels or face significant consequences (the “command and control” strategy), and by market-based instruments that change the nature of incentives and disincentives faced by polluters, encouraging action that benefits society.

Guidelines and standards are intended to be a means of forcing a business to change its operations in order to reach prescribed levels, increasing the cost to the business. In principle, the adverse environmental impacts of decisions in the power sector could be reduced by implementing more stringent standards than those currently applied in India. For this reason, the study attempted to estimate the incremental costs of implementing the World Bank’s new standards for air quality and emissions, which are more stringent for SO and suspended particulate matter (SPM) than current Indian standards. Analysts concluded that the incremental costs associated with meeting World Bank standards need not be substantial if plants are properly sited.

More significant benefits, however, will result from improved implementation of existing standards than from adoption of new and stricter standards. Participants in the National Decision-makers Workshop stressed that better implementation of monitoring and enforcement procedures will be of more immediate benefit to India.

Market-based instruments attempt to meet environmental objectives by working through market mechanisms. The common element of all market-based instruments is that they attempt to alter the behavior of economic decision-makers, such as firms and households, by changing the incentives and disincentives they face. For example, if ash disposal permits were allocated equally to all new power plants, regardless of their circumstances, some permits might be sold by those that find it easiest to meet the targets, which would reduce the total cost of compliance for all power plants. Other examples of market-based instruments include pollution or input taxes, product charges, and differential tax rates.

#### **2.1.5 Reducing and Recycling Combustion By-products**

In 1996/97 alone, coal utilization generated 62 million metric tons (mmt) of ash. The high ash content of Indian coal makes ash disposal one of the most pressing environmental problems India faces as a result of its reliance on coal-powered energy. The steady increase in open-cast mining, which now supplies the bulk of Indian coal, has been a major factor in the falling calorific value and rising ash content of Indian coal. Storage of fly ash demands large land areas; once land is used for this purpose, it is expensive to

reclaim for use in other ways. Often, this financial investment in land recovery is not made, and the land is simply lost.

The Andhra Pradesh and Bihar case studies clearly highlight the environmental hazards associated with current practices. In Andhra Pradesh, only 5% of the ash stock piled outside thermal plants is used by industries; the rest is dumped in ash ponds or left in piles outside the plants. In Barauni (Bihar), ash ponds are located on permeable sand, allowing groundwater contamination. Ash also has spilled onto local agricultural lands, and rivers in Patratu are said to be full of ash; during dry seasons, there are significant emissions of fugitive dust.

Not only does the ash cause environmental damage, it also increases the cost of transport to the power station site and causes wear and tear on equipment. Plants that burn the high-ash coal are intrinsically more expensive and less efficient because they must handle large quantities of noncombustible and abrasive matter.

To date, limited use has been made of coal washing, a process that removes some of the mineral matter that generates ash during burning. Because of the properties of Indian coal (it is difficult to separate mineral matter from carbon without also losing carbon), the economic tradeoffs for coal washing make it a controversial option. Consequently, situational analysis is needed to determine when transport is economically feasible. The Andhra Pradesh Case Study concluded that washing coal with marginally high ash content (30–38%), or with calorific values greater than 4,000 kilocalories per kilogram, may not be advantageous. However, as long as the total cost remains competitive with that of imported coal, coal washing is a viable alternative for coal with high ash content and low calorific value that must be transported over distances of more than 1,000 kilometers. Cost recovery incentives are essential, however, to make this option attractive.

An alternative approach to the fly ash problem is to encourage its use in a wide variety of commercial applications. To date, however, India has been less successful than other countries in encouraging commercial use of this waste material. In 1996/97, only 2% of the 62 mmt of ash produced by burning coal in India was used commercially. By comparison, China produced 55 mmt of ash and recycled 25% of it. The poor record in India is not for lack of possible applications relevant to the country's need. The greatest emphasis has been placed on its use in construction materials, since India has a chronic shortage of housing, and building materials are always needed. However, it is necessary to add binding reagents to ash and clay to meet applicable standards. As a result, the production of bricks from fly ash appears to be economical only when output exceeds 25,000 bricks per day, and the bricks are used within 50 kilometers of the production site. A variety of other applications are also promising. For example, fly ash may be used as filler, a soil conditioner, or a replacement for cement. However, there are obstacles to the use of these productive variations that planners must take into account. These include quality variations in the coal, transportation costs, technological limitations, impaired quality as a result of wet methods of coal collection and disposal, and consumer resistance to products that contain coal ash. Potential users also must consider:

- the price that industry must pay to the generators for the ash (if any), plus the cost of transportation;
- the cost of alternative materials;
- the impact of using coal ash and the quality of the end product; and,

- the impact that using coal ash has on the cost of the production process.

The National Thermal Power Corporation (NTPC), which runs thirteen coal-fired power plants in India, has been successful in increasing utilization of fly ash by developing policies to encourage entrepreneurs to make use of the waste. In 1991 it established an Ash Utilization Division at the corporate level, with Ash Utilization Cells at each power plant. Its six-year program to promote use of ash in internal construction and to facilitate use of ash by private companies succeeded in increasing ash utilization in its plants from 2 to 3% in 1991 to 10% in 1996/97. The corporation's incentives for entrepreneurial use included such policies as:

- dry-fly ash is provided free of cost to users in and around the power station for an initial period of five years;
- surplus land is made available for a discounted rent to companies that use ash; and,
- the corporation invests equity in joint-venture companies for ash utilization.

The NTPC's experience suggests that use of fly ash can be encouraged by changes in plant policy. Most plants, however, do not appear motivated to implement these policies. While power plants in theory are required to meet standards of ash disposal, in practice these standards often are not met. The poor compliance implies that the actual cost of ash disposal in Indian power plants is much lower than the costs in well-designed and well-managed systems. Many SEBs apparently are more likely to save money through poor ash-pond management than by encouraging industry to use ash. Consequently, the economic potential for use of ash in India is far from realized. The current problems of ash disposal and management could in part be corrected through stronger enforcement of present environmental standards.

Currently the government of India provides some fiscal incentives to encourage use of ash. Bricks and other building materials using 25% or more fly ash as raw material are exempt from excise duty. Also, imported machinery needed to produce building materials from ash are exempt from customs duty if not available within the country. The government has also taken several administrative actions:

- it has asked state governments to prepare action plans for using 50% of fly ash by the year 2000;
- it has asked State Pollution Control Boards to be lenient with industries that use industrial wastes; and,
- it has required environmental clearances for thermal power plants, emphasizing the need to arrange for dry-ash collecting and use.

Two additional policy options could stimulate increased use of fly ash:

- increasing utilization levels through binding targets imposed by the central government, which could be effective provided that the targets are well designed and geographically differentiated to reflect the economic potential for use of ash in different areas, and,
- a tax on ash disposal, which would have to be combined with power sector reform and commercial and regulatory incentives to have a significant effect (if environmental standards are enforced more strictly, however, the ash disposal tax will be unnecessary).

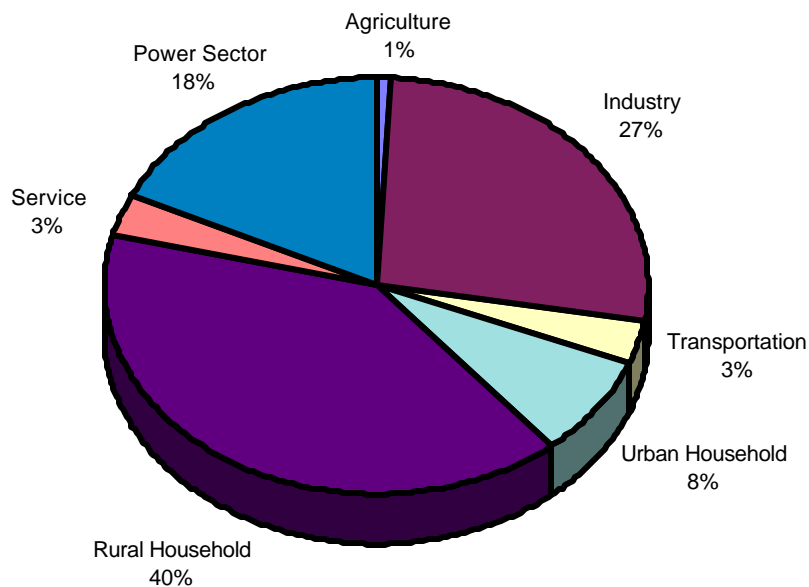
## **2.2 Case study in China**

The clean coal technology assessment and environmental control option case study in China started early in 1999. The project has been jointly funded by the Japan Consultant Trust Fund (JCTF) and Energy Sector Management Assistance Program (ESMAP). The major counterparts in China are the State Power Corporation (former Ministry of Electric Power), the Coal Bureau (former Ministry of Coal), the State Development and Planning Commission (SDPC), the State Economic and Trade Commission (SETC), and the State Environmental Protection Administration (SEPA). The study consists of three tasks:

- Technology assessment: we are looking at performance, cost, cost-effectiveness, technology readiness, and adaptability within China of all options in power and non-power sectors. In the power sector, particulate, SO<sub>2</sub> and NO<sub>x</sub> reduction technologies, including FGD, supercritical technology, circulating fluidized bed combustion (CFBC), PFBC, and IGCC have been studied. In non-power sectors, studies have focused on coal briquetting, screening, washing, coke making, and coal gasification for industrial and town gas use.
- Case studies: this is the third case study in a row; we have completed studies in the Shanghai metropolitan area and Henan province.. Based on the energy supply and demand forecast for the next twenty years, the model defined the least-cost system-expansion scenario as the base case, then added environmental factors by making several scenario studies or least-cost studies for assumed environmental targets. We are now looking into Hunan province, adding cost analysis for dispersion and environmental impact by contracting Tsinghua University (a bottom up approach) to improve the reliability of analytical results.
- Clean Coal Technology site tours and workshop: we have arranged for Chinese technical experts to visit CCT commercial and demonstration plants in Japan and Europe, and discuss plant operation with maintenance managers; a CCT Workshop was held in Beijing in December 1999 to disseminate the results and methodology of the CCT study.

The study team went on two missions to China in March and April/May, visiting power stations in Shanghai, Shangdon, Shanxi, Hunan and Sichuan provinces, and the boiler manufacturers of Harbin, Dongfang and Shanghai. The team is finalizing the results of the Hunan study.

**TSP emissions in Henan, 1997**  
**Total emissions: 2,391,000 tons**



**Figure 6. Henan, particulate emissions from various sectors**

Figure 6 shows particulate emissions from various sectors in Henan province. Large amounts of particulates come from coal burning in rural households and industrial boilers. Considering the distance from emissions sources to the impact points, these sources are much closer to the affected people than the tall chimneys of power plants, and the health impact apparently is far greater. It was concluded that cost effective ways of reducing particulate emissions were countermeasures such as switching from raw coal to briquettes in rural households, from raw coal to coal gas in urban households, and from raw coal to briquettes at industrial boilers.. In contrast to the boilers used by utilities, industrial boilers are difficult to replace with large-scale boilers, so switching to cleaner fuels and changing combustion methods (to fluidized bed combustion, for example) would be necessary countermeasures.

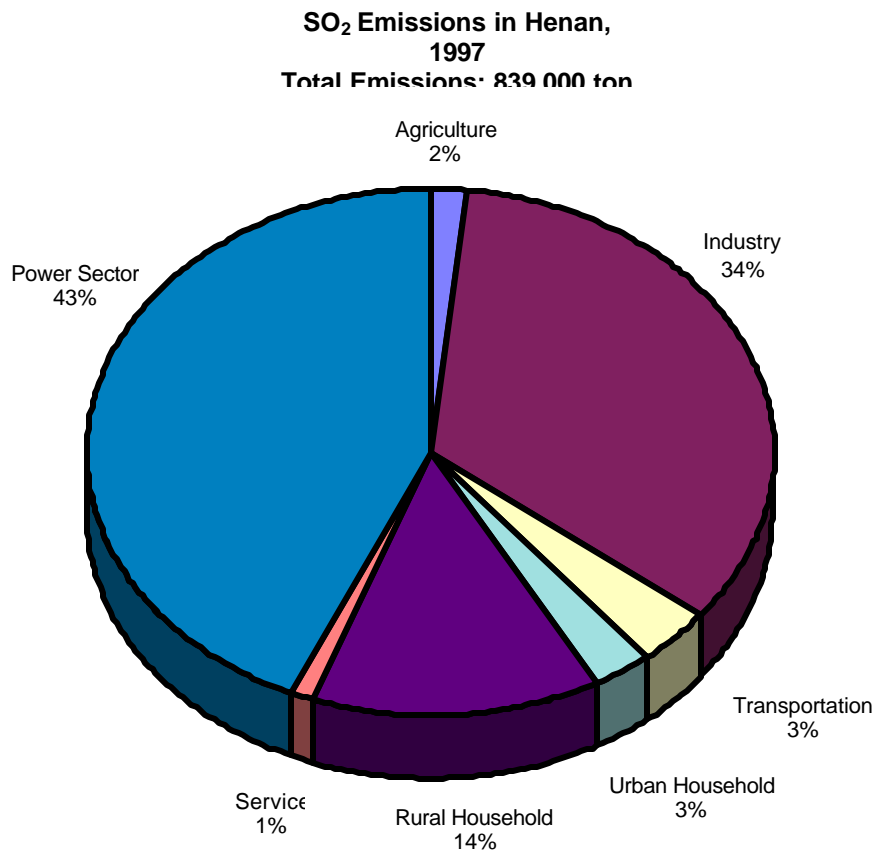
### **2.2.1 Retirement and rehabilitation of small inefficient plants**

Around 18% of particulate emissions in Henan come from power sector boilers. Within the power sector, 73% of particulate emissions (13% of the total) come from small power plants (less than 125 MW), while larger plants (larger than 125 MW) emit only 27% (5% of the total). Small plants, such as 6 MW, 25 MW and 50 MW, need to be retired as scheduled.

The Chinese government has set a target that 30 GW of small plants will be retired by 2003. However, many small plants do not belong to State Power, but to local governments or Town and Village Enterprises (TVE), and a directive to close small plants may not be effective with these plants. With the opening of the economic market in the late 1980s and early 1990's, many small TVE mines have been developed, and small plants using coal from these small mines have been built. Internalizing environmental

costs should therefore come together with the opening of the market. Especially the number of small plants is large, and monitoring and enforcement costs are expected to be huge. A thorough investigation must be conducted to see how such costs can be minimized, and it has to be clearly defined who will bear the costs.

The mid-size plants (100–200 MW) will not be retired soon. Rather, they will be rehabilitated and operated for a longer time. Many of these plants do not have electrostatic precipitators (ESP), which can control particulate emissions efficiently; the study shows that retrofitting these plants to use ESPs is a very cost-effective way of reducing particulate emissions.



**Figure 7. Henan SO<sub>2</sub> emissions from various sectors**

Figure 7 shows the reduction in SO<sub>2</sub> emissions and the cost-effectiveness of various options in the power and non-power sectors, from low-cost to high-cost. Options that can reduce the extensive SO<sub>2</sub> emissions in the power sector include simplified FGD and wet FGD, the most cost-effective options.

### **2.2.2 Flue Gas Desulfurization**

It is not necessary in China, nor are there enough financial resources, to install FGD in all power plants, as done in Japan and Germany. The priority must be to put FGD in plants that use high-sulfur coal in regions and cities where the SO<sub>2</sub> emissions have already caused environmental damage. It will be necessary to recover the cost of capital investment, and operation and maintenance by incorporating these costs into the

electricity tariff. Environmental costs will be additional for such plants, and the tariff difference between them and plants that do not have FGD needs to be compensated by internalizing environmental costs. There are several ways of internalizing these costs. One way is through environmental regulations, as done in Japan, and other ways include emission credits trading, and emission fees and taxes. We need to identify the most effective way given Chinese situation.

### **2.2.3 Supercritical technology and Circulating Fluidized Bed Combustion**

There are already ten supercritical units operating in China. Eight units are made by Russian technology, and two units at the Shidongkou II plant in Shanghai are 600-MW supercritical boiler and turbine units made by ABB. The study team visited the Shidongkou plant and Panshan plant that have Russian made 500-MW supercritical units. In both plants, supercritical units have been operated at high availability. The plants have sent their operation and maintenance staffs for training at overseas equipment suppliers, developed training programs of their own, and acquired enough operation and maintenance capacity to run supercritical units.

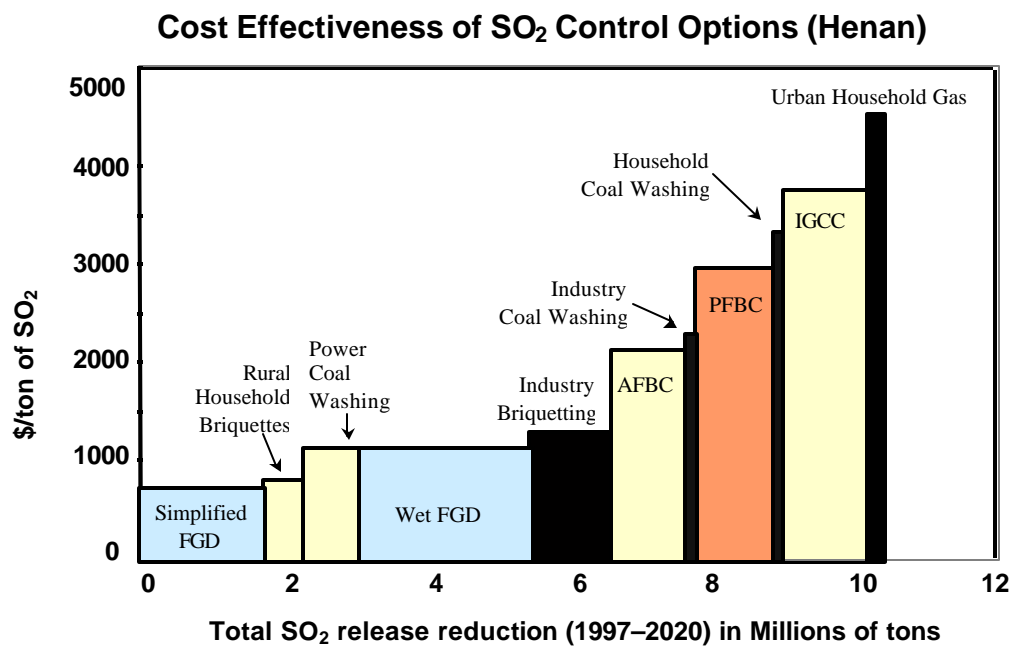
To investigate the level of manufacturing capability, we visited three domestic boiler manufacturers: Harbin, Dongfang and Shanghai Boiler Works. By introducing machines from Japan and Europe, they have acquired necessary technologies, such as welding boiler tube panels, to manufacture supercritical units. But they need to import high-temperature materials that they cannot find from domestic suppliers, and they don't have experience to build supercritical units. Therefore they will not be considered qualified bidders, for example, in the project financed according to procurement guidelines by the World Bank.

On the other hand, the Chinese government has made it a high priority for domestic manufacturers to acquire overseas advanced technologies to reduce production costs and promote domestic employment. There are a couple of joint ventures between domestic and overseas manufacturers. To promote deployment of clean coal technology in China, these processes should be accelerated. We have continued a dialogue with the Chinese government on how to promote technology transfer with fairness and transparency, and how the World Bank can help establish policy.

Accommodating the interests of overseas technology suppliers and domestic manufacturers is a big issue. We are trying to promote dialogue between representatives of overseas industrial groups and the Chinese government. We had an advisory group meeting of experts on supercritical technology and FGD in conjunction with the CCT workshop in Beijing in December. Siemens, Germany coordinated the industrial group as a leader of supercritical technology meeting, and Hitachi lead the FGD industrial group. A 100-MW plant using CFBC technology is in operation in Gaoba, Sichuan province. Through use of European technology, its operators have acquired good operation and maintenance experience with CFBC. The plant uses high-sulfur coal produced in Sichuan province, and the CFBC is a cost-effective technology to burn such coal cleanly. Domestic manufacturers have established the capability of building CFBC units up to 100 MW in size, and the manufacturers we visited have been receiving many orders for CFBC boilers.

In Baima power plant near the Gaoba CFBC plant, they are planning to build a 300-MW CFBC. Three European and US CFBC manufacturers are bidding on the project, and

technology transfer is stipulated in the bidding document. The Chinese government intends to get the license from an overseas technology supplier for the three domestic manufacturers, who will share knowledge and the licensing fee. Compared to Japan, Europe and the US, this is a quite different way of licensing arrangements, and fair and transparent rules need to be established to promote competition along with technology transfer.



**Figure 8. SO<sub>2</sub> cost effectiveness in Henan**

#### 2.2.4 Combined-cycle Generation (PFBC and IGCC)

There are a couple of coal-based combined-cycle projects planned in China. In Dalian, Liaonig province, and in Jiawan, Jiansu province, they plan to build two 100-MW PFBC units that will serve as combined heat and power generating plants. In Yantai, Shangdon province, they are planning to build a 400-MW IGCC plant, and in Yanzhou another IGCC project is proposed to produce chemical feedstock as well as 400 MW of electricity. .

There are several PFBC and IGCC demonstration projects going on in Europe, the US and Japan. However, these advanced technologies have not reached the commercial stage and are still reducing risks and costs as they advance along the learning curve. Projects using these technologies have too many unfavorable conditions from the viewpoint of the World Bank, which avoids risk to ensure capital investment recovery and minimize investment costs. However, when we look at the long term, fifty years or a century from now, when global environmental issues and limitations on natural resources matter, we have to think beyond the usual business standards. The Global Environmental Facility (GEF) was established to cope with such long-term problems, and it has funded mainly renewable projects.

However, renewable energy can cover only a small part of the reduction in CO<sub>2</sub> concentration. Efficient use of coal would reduce large amounts of CO<sub>2</sub> and provide cost-effective options. The GEF has an apparent preference for renewable energy, but for the benefit of developing countries, we should favor clean coal technologies through reasonable investment in fossil energy projects. This will only be possible when government representatives to GEF, and industrial and academic representatives, support such facts and views.

The GEF fund is not necessarily combined with the IBRD loan. It could be used in combination with the OECF loan or private loans. In case of private financing, technology suppliers or developers need to cover the technology risk. However, if the risk is too large at the initial stage for private industry, the GEF would consider insuring a partial technical risk.

PFBC and IGCC projects in China will only be possible by sharing the technical, commercial and financial risks with private and public entities: the private technology supplier's investment and partial technical risk guarantee; local financial support by the Chinese government supporting its development strategies; and mechanisms such as the GEF grand and partial technical risk guarantees, or bilateral aid.

### **3) RECOMMENDATIONS (ACTION PLAN TO PROMOTE CCT WITH WBG)**

<b>Recommendations (Actions for Working Together in CCT)</b>
<b>1. Policy advise to WBG/GEF</b> <ul style="list-style-type: none"><li>- through ED's, Board members</li><li>- through industrial advisory group</li></ul>
<b>2. Dissemination of CCTA/ECOS</b> <ul style="list-style-type: none"><li>- interested countries in EA, SA, ECA</li><li>- Energy Environmental Review</li></ul>
<b>3. Public/Partnership</b> <ul style="list-style-type: none"><li>- Knowledge Management</li><li>- ESMAP</li></ul>

**Figure 9. Recommendations**

#### **3.1 Development of WBG and GEF's clean coal program**

To include clean coal in the agenda of WBG and GEF as in the case of renewable energy and mainstreaming the clean coal to the financing, investment and guarantee projects. Conventional coal-fired power generation projects are not likely be financed by the World Bank's loan nor credit. There are three points need to be considered as future direction:

- Promote sector reform and power sector deregulation and help private sector investment
- Help setting rules and regulations taking into account environment
- Help establishing strategies of acquiring or developing new technology

WBG can support private projects through IFC loan or investment or MIGA and IBRD's insurance or guarantee operation. We could help developing countries by providing advice on environmental regulations and institutions and new-technology acquisition and development through our experience in Japan, Europe, and the US. This is not direct lending operation but "Knowledge Management," a new direction of the WBG.

### **3.2 Disseminating Clean Coal Technology Assessments and Case Studies**

The methodology of technology assessment and case studies has been applied to China and India but also could be applicable to other countries in Southeast Asia, South Asia, the former Soviet Union, and Eastern Europe. For this purpose we will hold workshops and seminars to disseminate the methodology and results of studies so that their applicability is well understood. The framework for the methodology has already been developed. Financial resources to conduct studies will be available. Therefore, if you are interested in applying the methodology, let us know. We could also extend the methodology to accommodate more comprehensive energy and environmental reviews that cover whole energy sectors, and we would be able to give quantitative advice systemwide over the long term, which would be different from what we had in project-specific feasibility studies and environmental assessments.

### **3.3 Participation in WBG programs**

There are many ways of working with the WBG, including as a technology partner. Technology partnerships gather and manage knowledge through knowledge databases created with private industry in particular areas to share with experts in developing countries. We have started partnerships with Siemens and EPRI and created web sites with pages on CCT, supercritical technology, gas turbines, and Biomass gasification, published as Energy Issues.

#### **World Bank & related web sites**

- **Environmental Management for Power Development (including CCT)**  
[www.worldbank.org/html/fpd/em](http://www.worldbank.org/html/fpd/em)
- **Energy and Environment Strategy (Fuel for Thought)**  
[www-esd.worldbank.org/cc/wbstrat.html](http://www-esd.worldbank.org/cc/wbstrat.html)
- **Pollution Prevention and Abatement Handbook (Environmental guideline)**  
[www-esd.worldbank.org/pph](http://www-esd.worldbank.org/pph)

**Figure 10. Sources of information**

Figure 10 shows our web site address and the addresses of related sites. The first one is our web site called EM PowerInfo; the web pages with our technology partners are available on this site. Also available here are the Clean Coal Program and the update on technology assessment and case studies. . Related sites feature Energy and Environmental Strategies, and the Pollution Prevention and Abatement Handbook presented today. We are now adding partners and extending the topics to FGD, PFBC, transmission and distribution technology, and distributed generation.